Project ID#: EEMS060
Pillar: Multimodal

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Agent-Based Model and Data Collection for Inter/Intracity Freight Movement

Monique Stinson
Argonne National Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 12, 2019

PROJECT OVERVIEW

Timeline	Barriers
• Project start date : Oct. 2018 • Project End date : Sep. 2019 • Percent complete : 50%	• High uncertainty in technology deployment, functionality, usage, impact at system level • Computational models, design and simulation methodologies • Lack of data on individual behaviors relating to e-commerce and freight • Integration of disparate model frameworks
Budget	**Partners**
• FY18-19 Funding: $525,000 • FY18 Funding Received : $450,000 • FY19 Funding Received : $75,000	• Argonne (Lead) • ORNL, NREL, INL, LBNL • Rensselaer Polytechnic Institute (RPI) • George Mason University (GMU) • American Trucking Research Institute (ATRI) • Chicago Metropolitan Agency for Planning (CMAP), IHS-Global Insight, Chicago Dept. of Transportation (CDOT), Federal Highway Administration (FHWA)

PROJECT RELEVANCE

Challenges:

- MDT & HDT (Medium & Heavy Duty trucks) not in any agent-based lab models pre-FY19
- Establishment and driver behavior is key–must calibrate models with limited data

Objectives and Relevance:

- Estimate the **energy and mobility impacts** of freight
    - Model commercial activity and goods movement at **intraregional & intercity** levels
    - Address interdependencies between **commercial and household** activity
    - Develop agent-based model & analyze **e-commerce impacts** on freight
- **High impact: Trucks constitute 10% of traffic and 30% of transportation energy**

FY19 Q1

- Base-year truck trips
- Assign trips to parcels
- Truck agents
- Agent-based framework design

FY19 Q2

- Future scenarios: truck trips
- Implement e-commerce deliveries for base & future
- Vehicle technology penetration

FY19 Q3

FY19 Q4

- Implement existing, supply chain, agent-based model
- Calibrate for Chicago region
- Complete e-commerce analysis

MILESTONES

19Q1

19Q2

Complete intra-city and inter-city POLARIS freight model **(top-down)**

19Q3

Complete initial intra-city and inter-city POLARIS freight model **(agent-based)**

Demonstrate effectiveness of POLARIS-FREIGHT model to assess freight related energy use

19Q4

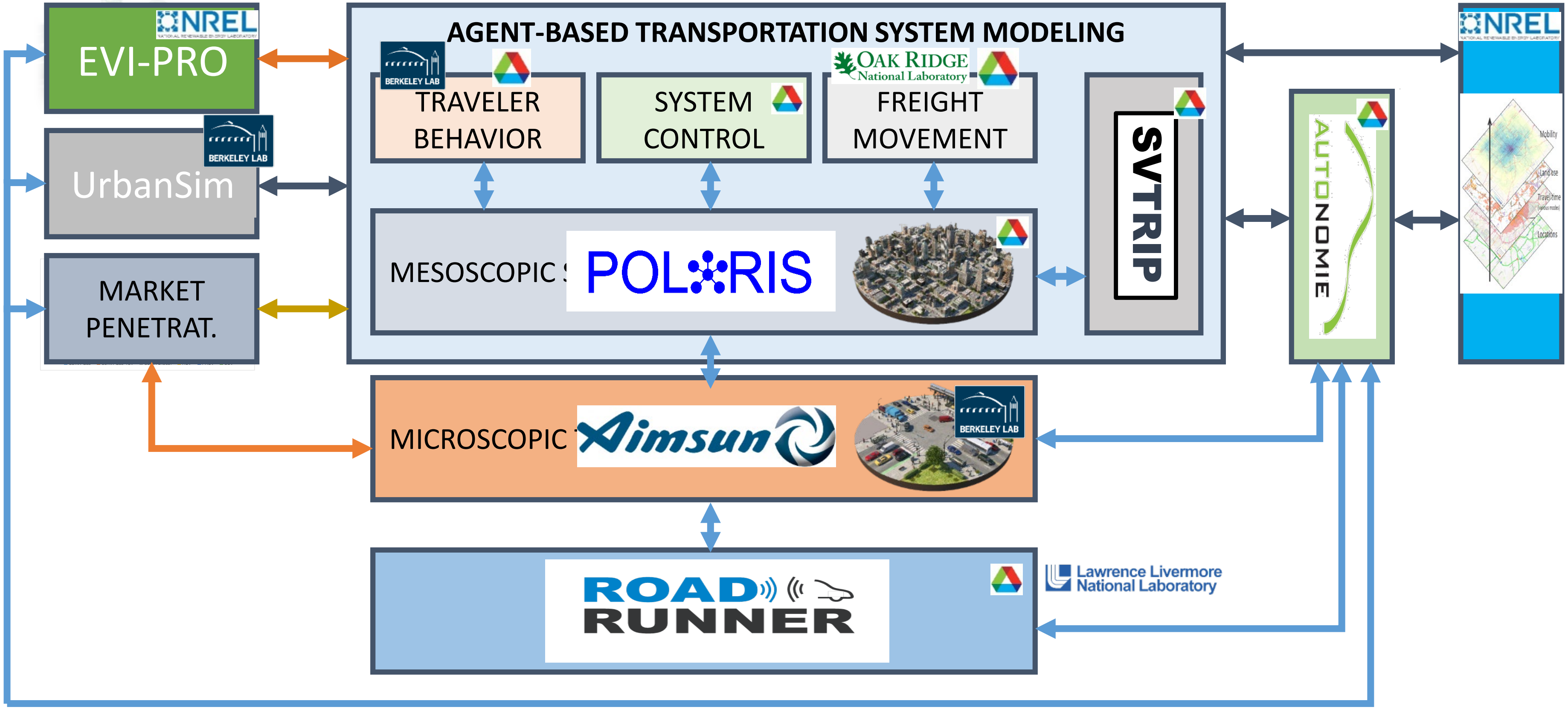
Quantify the impact of e-commerce on mobility and energy using POLARIS freight model

- Task completed
- In progress
- On track

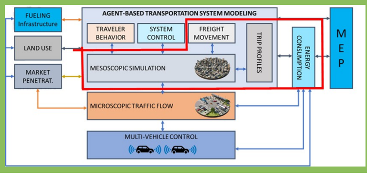
APPROACH

APPROACH - SMART WORKFLOW
A COMPREHENSIVE APPROACH TO ANSWER COMPLEX QUESTIONS

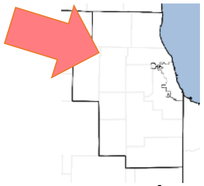
EEMS058



FREIGHT ANALYSIS APPROACH

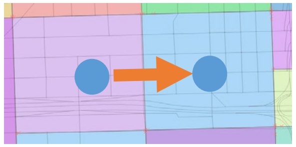


COMMODITY FLOWS



FAF*

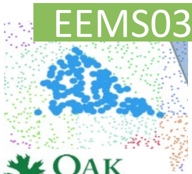
REGIONAL TRUCK TRIPS



CMAP

PARCEL DELIVERIES

EEMS034



“TOP-DOWN”: ADD DETAILS

SPATIAL
CMAP, CDOT

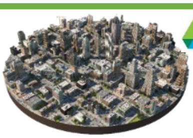
TEMPORAL
FHWA

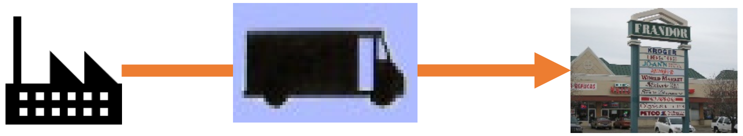
SCENARIOS
- COMMODITY FLOWS
- E-COMMERCE
- MARKET PENETRATION

FREIGHT MOVEMENTS

POLARIS

EEMS017





EEMS058

SVTRIP

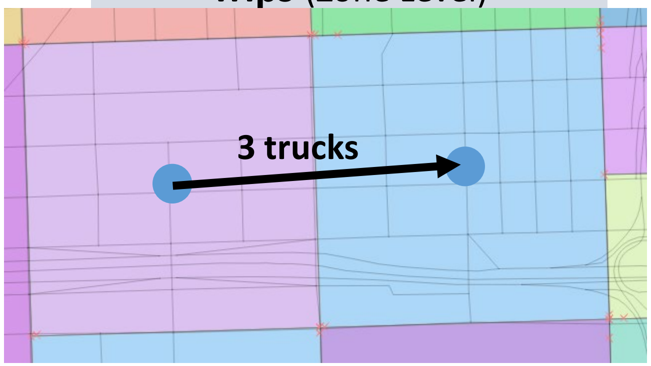
AUTONOMIE

*Freight Analysis Framework (FAF)

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

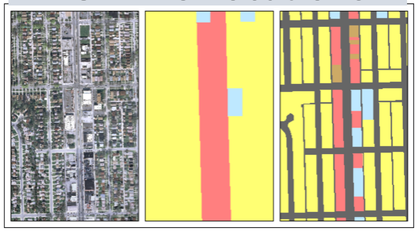
CREATED CURRENT AND FUTURE FREIGHT ORIGINS AND DESTINATIONS USING SPATIAL FLOW DISAGGREGATION

CMAP Commercial Vehicle Trips (Zone Level)

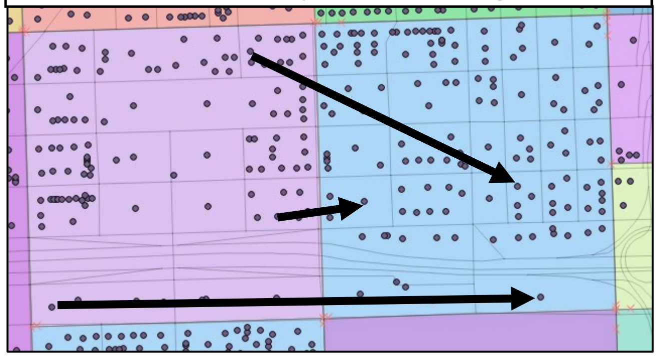


Spatial Disaggregation: Assign to Detailed POLARIS Locations

- Chicago DOT Buildings Data
- CMAP Land Use / Industry



Base-Year Trips: Truck Agents



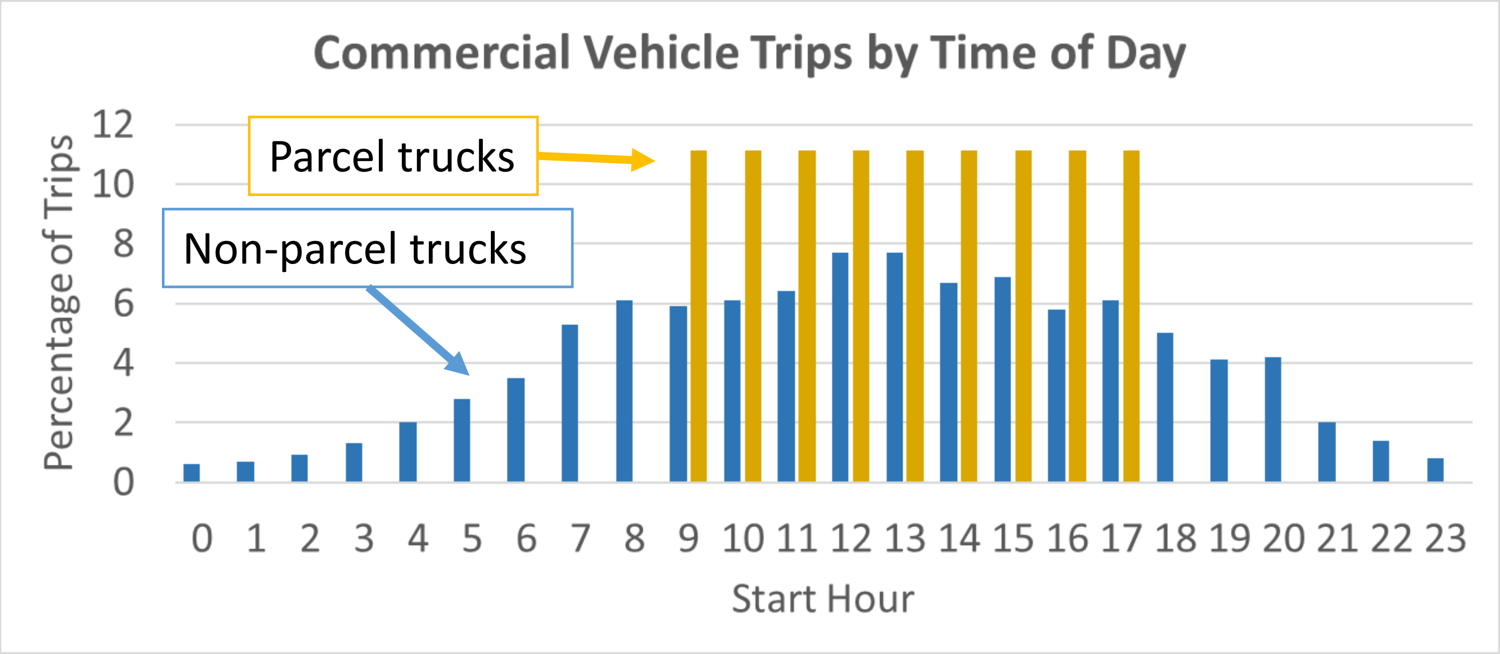
Apply FAF Chicago Regional Growth Rates (Moderate, High) to Base Year ODs

Freight Analysis Framework Version 4

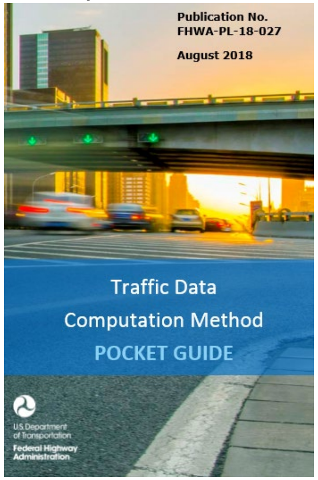
Future-Year Truck Trips

DETERMINED START TIMES OF FREIGHT TRIPS

- Necessary for Dynamic Traffic Assignment
- Developed algorithm to convert trips from daily rate to start time (in seconds)

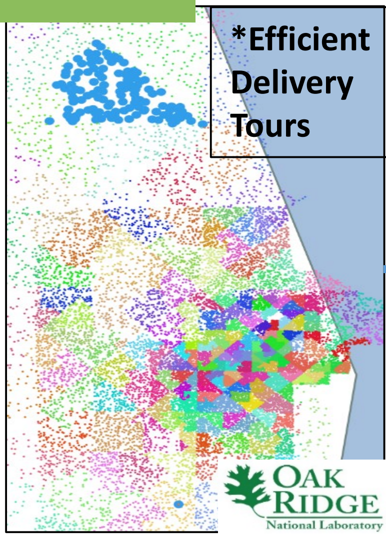


Non-parcel source:



DEVELOPED AND IMPLEMENTED METHODOLOGY TO ASSESS E-COMMERCE IMPACTS

EEMS034

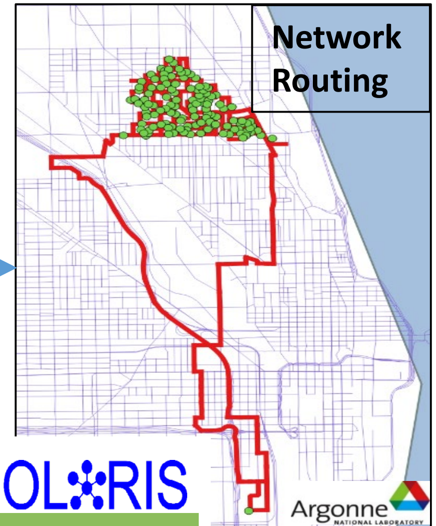


Base year:

Zone-Level: Total Parcel Deliveries

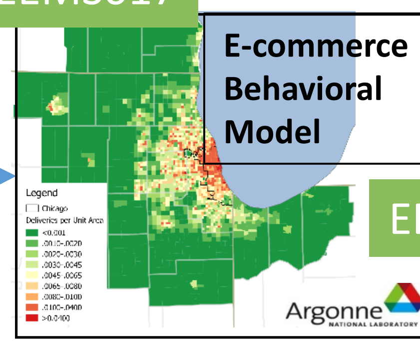
Stop-Level: Random Delivery Locations

MDT Delivery Tours



POLARIS

EEMS017



EEMS078

SVTRIP

AUTONOMIE

EEMS058

Survey Data

WholeTraveler

EEMS023

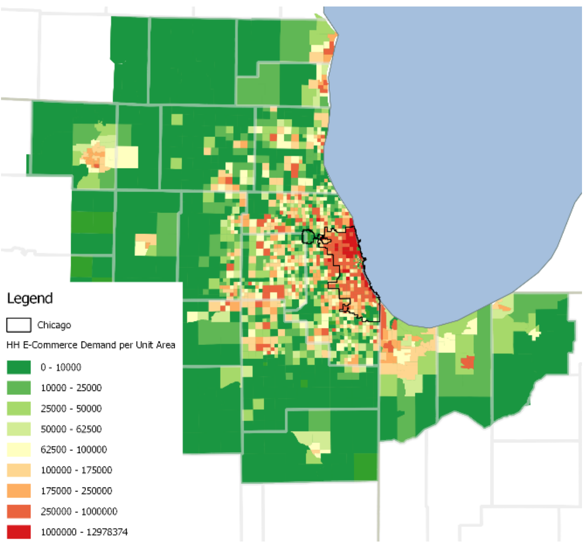
*Efficient Delivery Tours: No express/1-2 hour delivery yet

VISUALIZING BASELINE E-COMMERCE ACTIVITY SHOWS HOW HOUSEHOLD DEMAND AND DELIVERY TRUCK SUPPLY INTERACT

From delivery demand and supply… **…to modeled trucks on the road:**

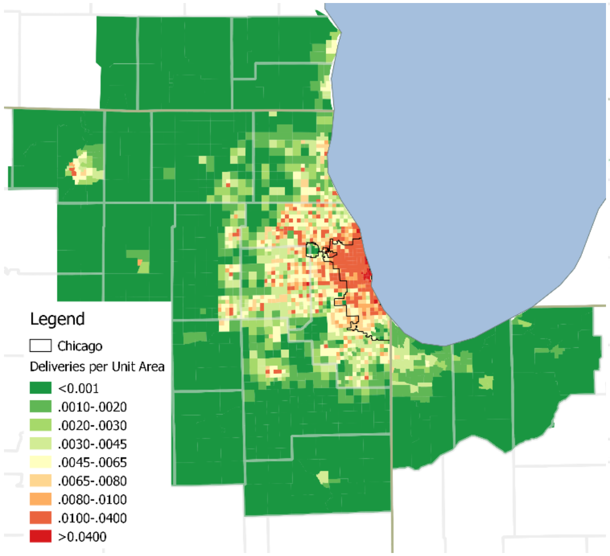
EEMS078

HH delivery demand
(area-based intensity)

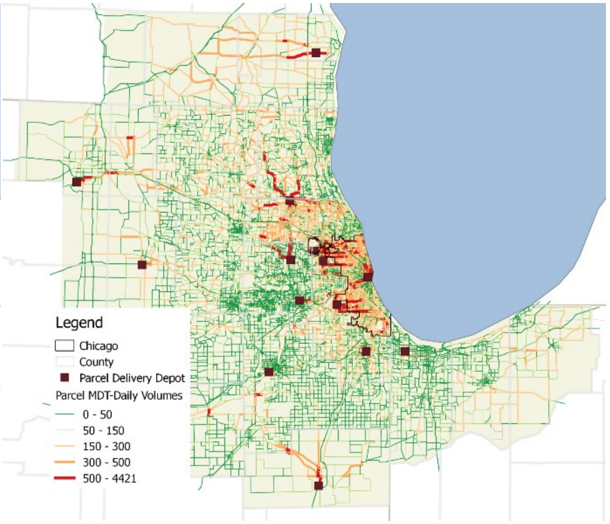


EEMS034

Parcel delivery trucks
(area-based intensity)

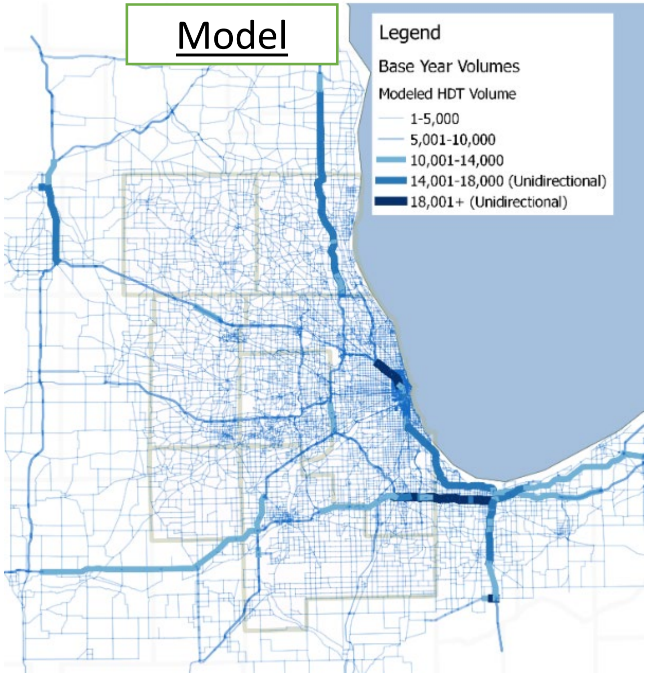


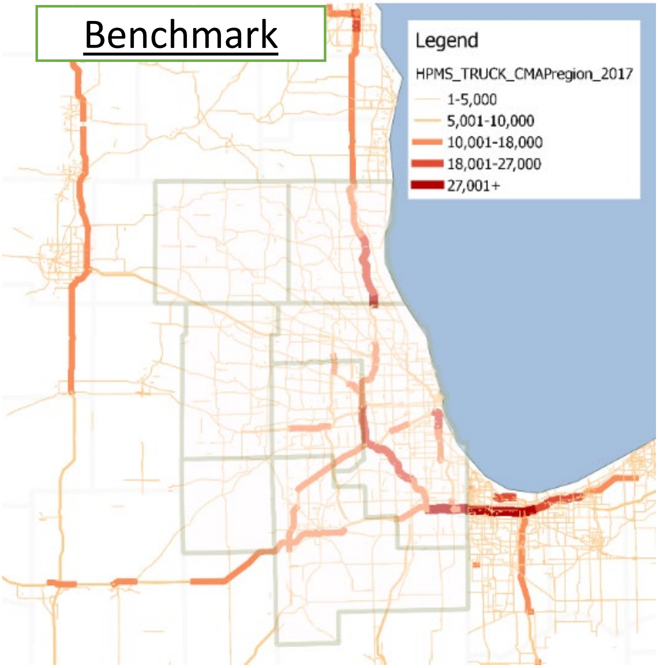
Parcel MDT volume
(link-based intensity)



VALIDATED MODEL FOR BASELINE VOLUMES, VMT & ENERGY

24-Hour HDT



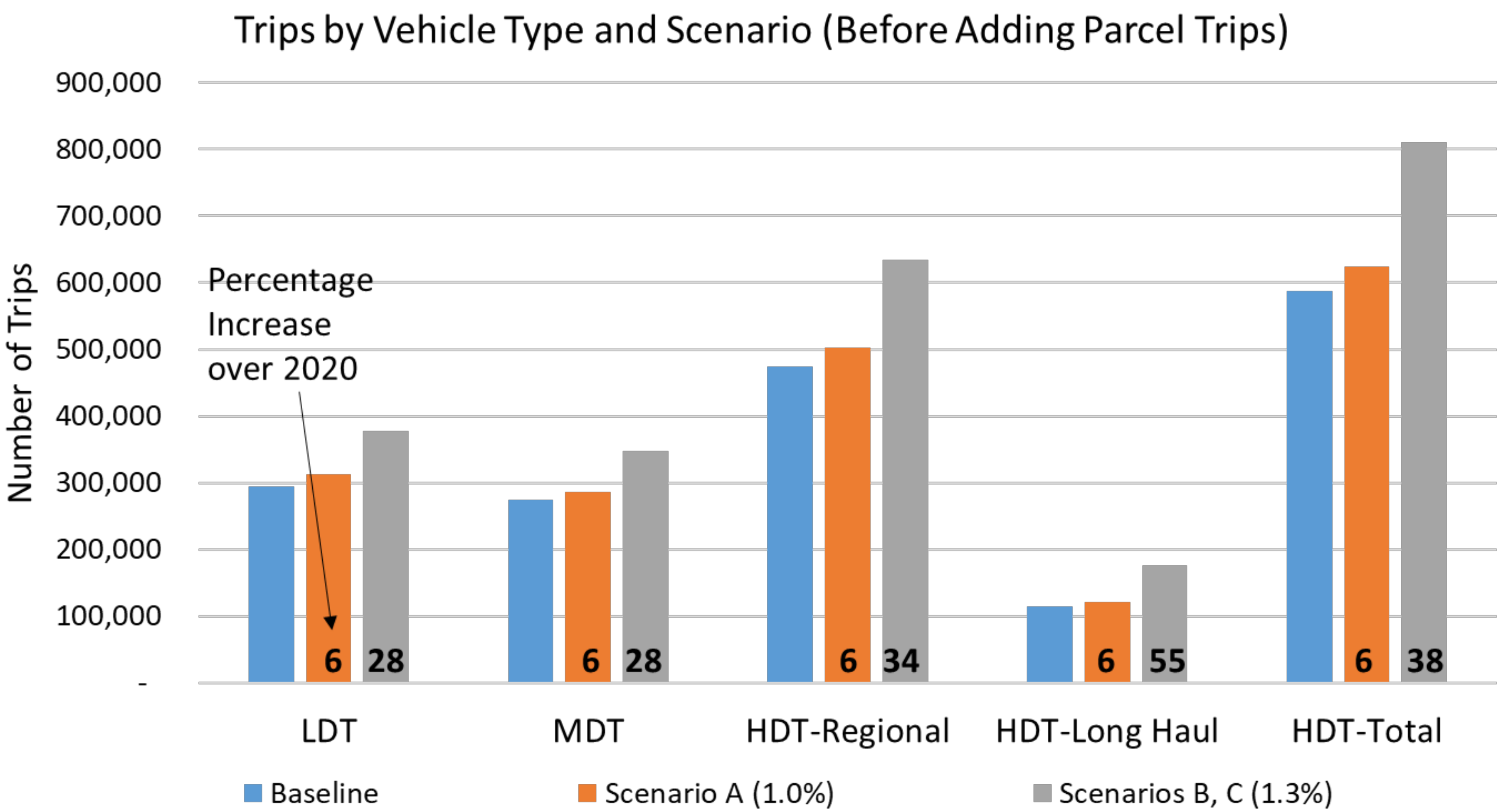


Vehicle-Miles Traveled (VMT) and Fuel Shares

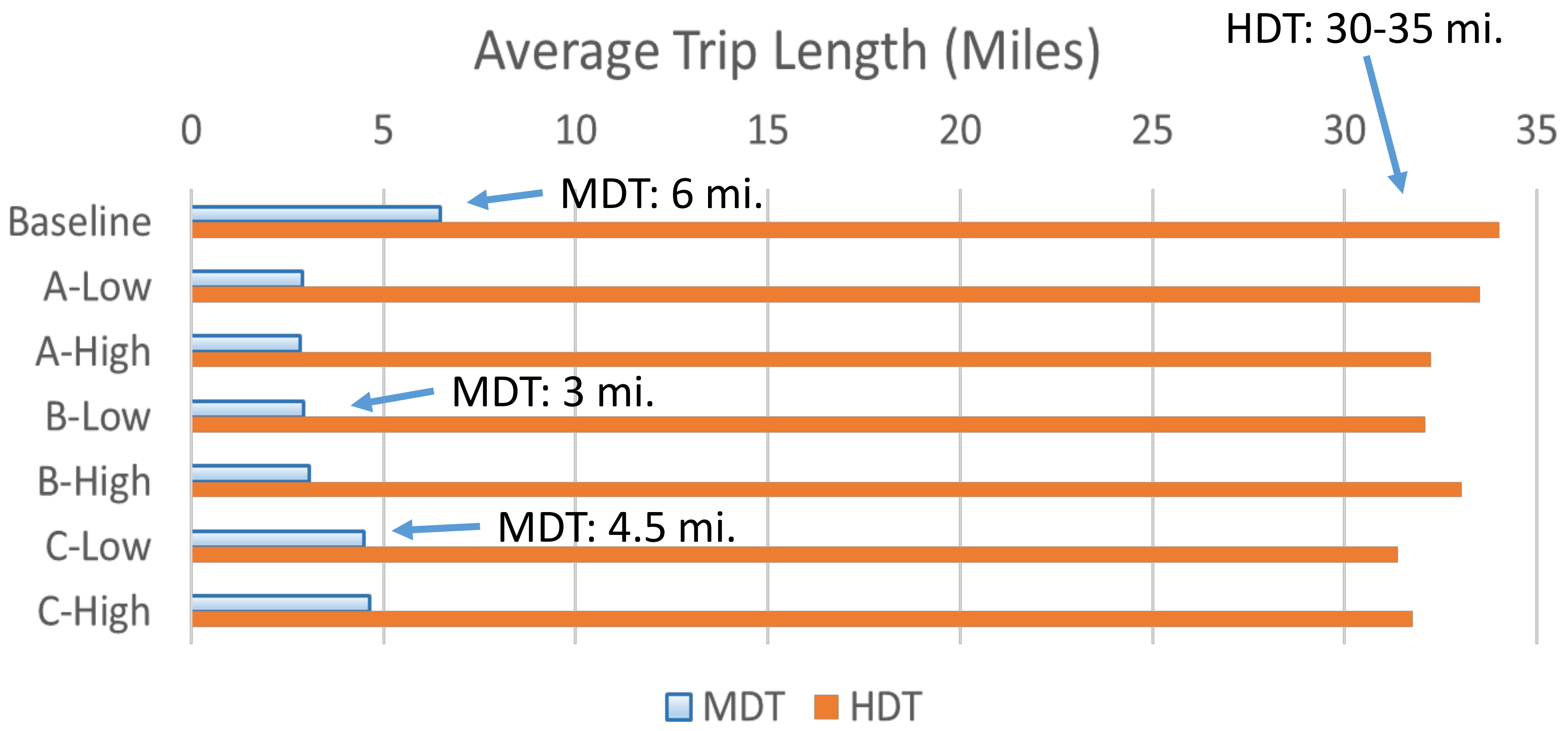
MDT*, HDT Share	Model	Benchmark (Nat'l. Average)
VMT	8%	10%
Fuel	36%	30%

Sources: *USDOT Beyond Traffic 2045 report incl. special tabulation prepared by the Bureau of Transportation Statistics; 2017 HPMS-Highway Performance Monitoring System)*

GROWTH IN COMMODITY FLOWS HAS GREATEST IMPACTS ON INTER-CITY HDT



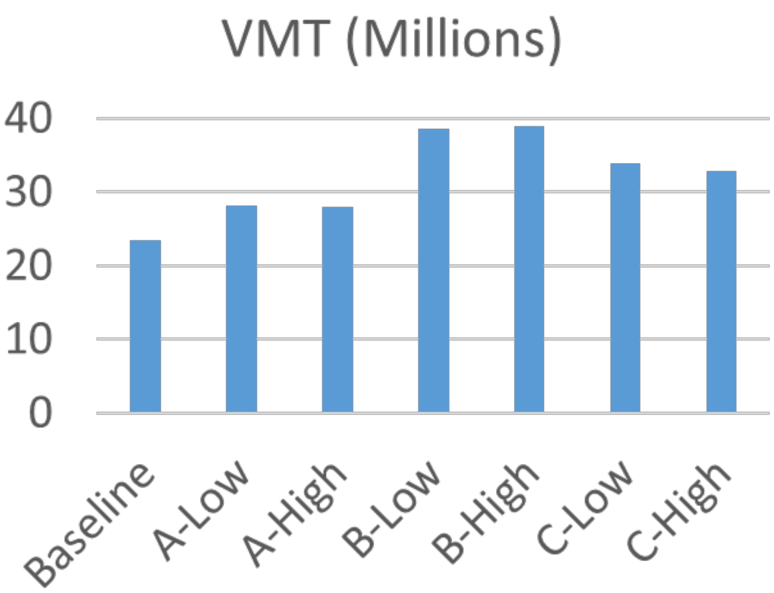
VOCATION AND E-COMMERCE DELIVERY FREQUENCY ARE MAIN DRIVERS OF MDT, HDT TRIP LENGTHS

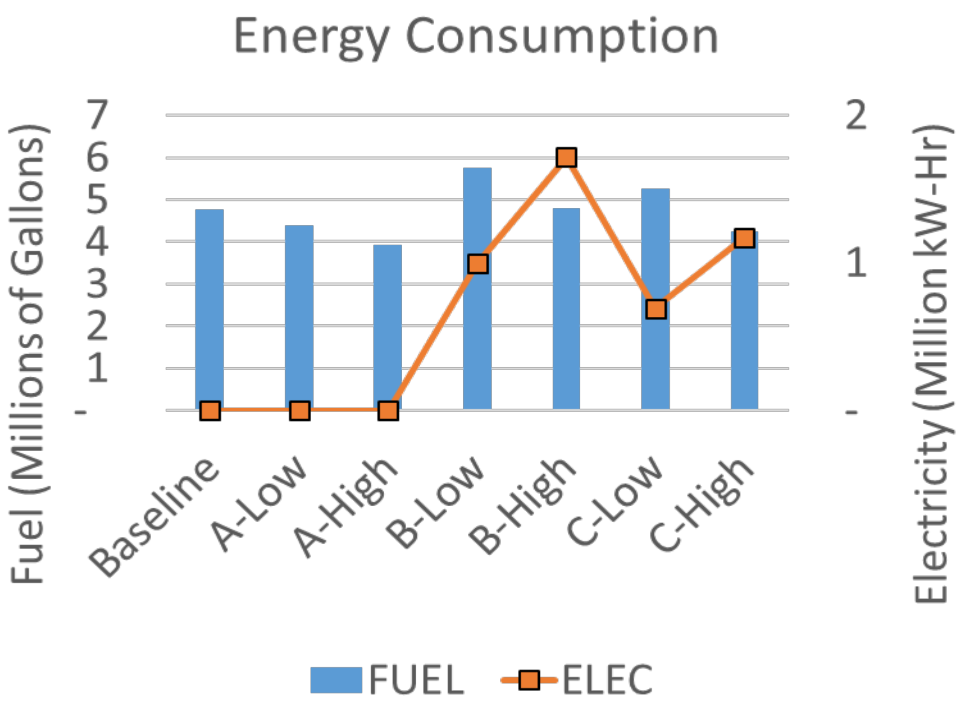


Scenarios—household delivery rate:

- Baseline: ~1 delivery per week
- A & B: 7 deliveries per week
- C: ~3-4 deliveries per week

E-COMMERCE, COMMODITY FLOWS DRIVE INCREASE IN TRUCK VMT IMPROVED TECHNOLOGY REQUIRED TO MITIGATE FUEL CONSUMPTION





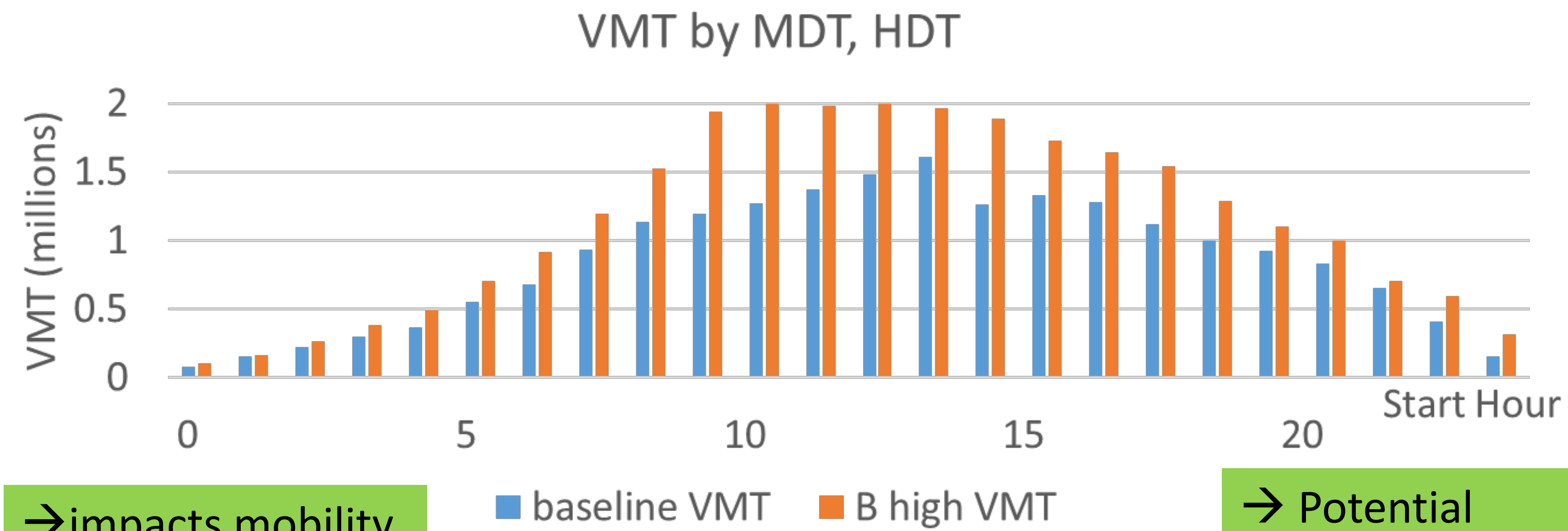
<u>Scenarios—commodity flow growth:</u>

- A: Moderate
- B & C: High

<u>Scenarios—household delivery rate:</u>

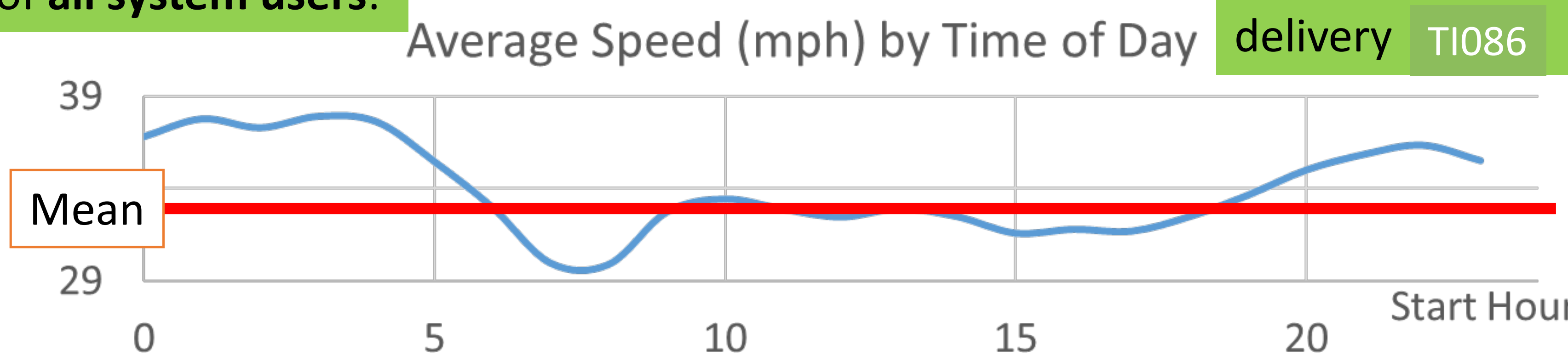
- Baseline: ~1 delivery per week
- A & B: 7 deliveries per week
- C: ~3-4 deliveries per week

E-COMMERCE DELIVERIES CONCENTRATED IN DAYTIME: IMPACTS NETWORK IN BUSIEST TIMES

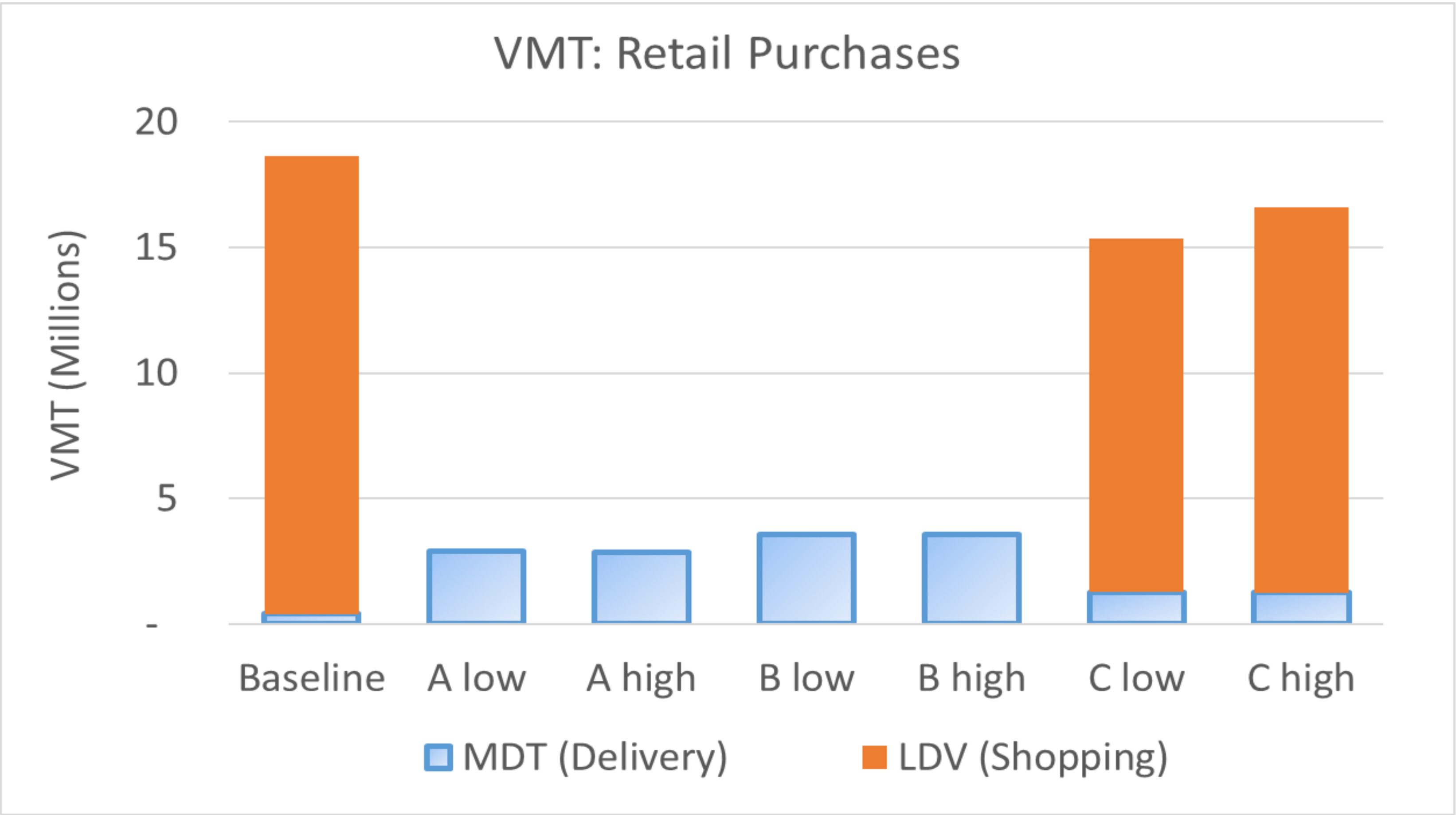


→impacts mobility of **all system users**:

→ Potential solution: Off-hours delivery TI086



EFFICIENT E-COMMERCE DELIVERY SYSTEM REDUCES VMT RELATED TO SHOPPING



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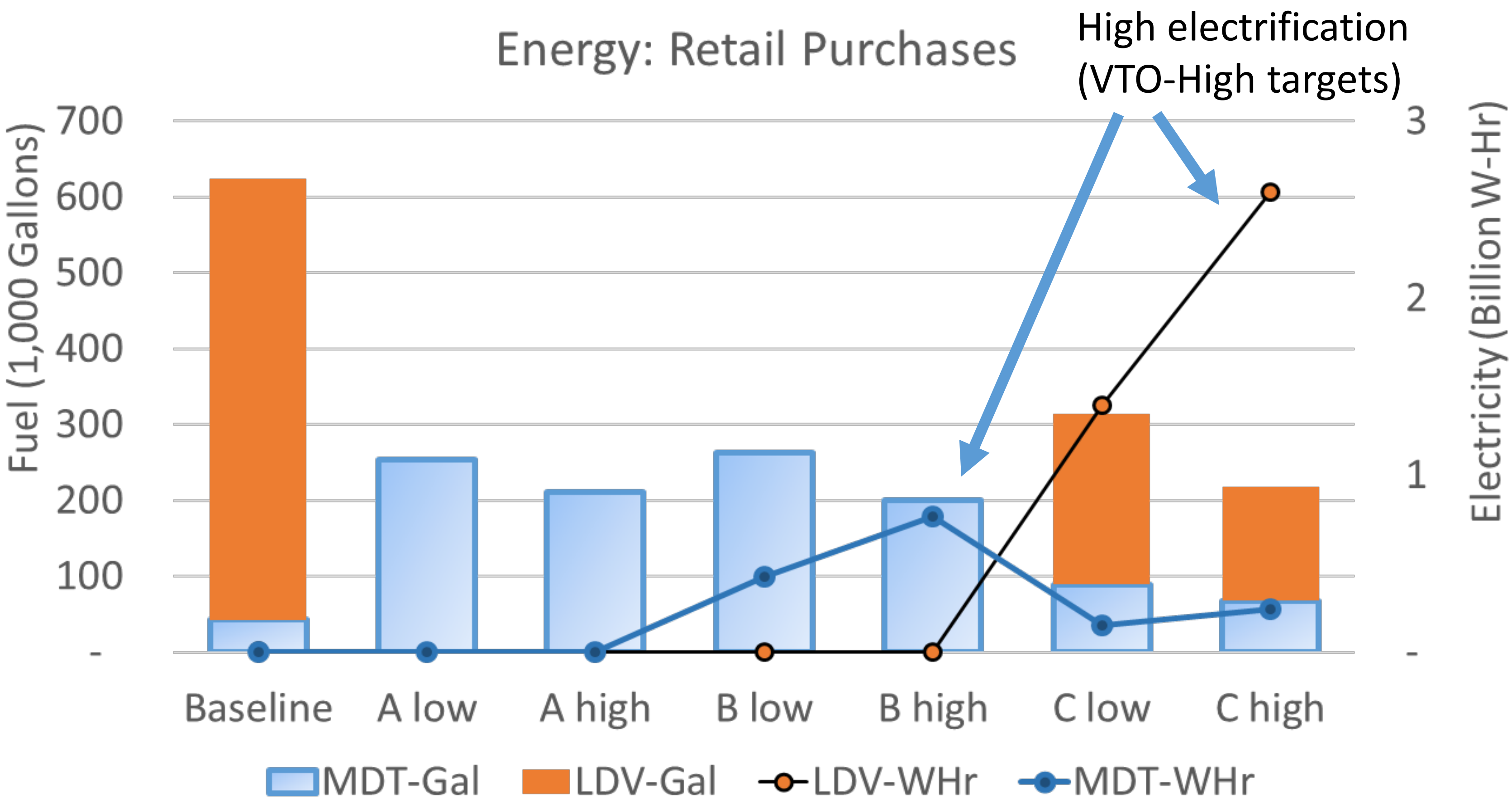

Scenarios—household delivery rate:

- Baseline: ~1 delivery per week
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- C: ~3-4 deliveries per week

RESPONSES TO PREVIOUS YEARS REVIEWERS COMMENTS

- This project was not reviewed last year

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

U.S. Department of Energy SMARTMOBILITY	EEMS034, EEMS078, EEMS023
Oak Ridge National Laboratory; IHS Markit	Parcel delivery tours (EEMS034); commodity flows (FAF); vehicle market forecasts
Argonne National Laboratory; Berkeley Lab; INL Idaho National Laboratory	E-commerce model (EEMS078) using WholeTraveler data (EEMS023)
NREL National Renewable Energy Laboratory	Vehicle market forecasts; Collaborating for future linkage esp. Freight Mobility Energy Productivity (MEP)
Rensselaer Polytechnic Institute; George Mason University	Energy Efficient Logistics (TI086): Rensselaer Polytechnic Institute (RPI), George Mason University (GMU)
CDOT Chicago Department of Transportation; CMAP	Local data providers
U.S. Department of Transportation Federal Highway Administration	Data on commodity flows (FAF) and traffic volumes
ATRI American Transportation Research Institute	American Trucking Research Institute (ATRI)

REMAINING CHALLENGES AND BARRIERS

- More data on e-commerce
- Improving the interaction between demand and supply in e-commerce
- Bottom-up (fully agent-based) approach required to have more detailed information on each vocation

FHWA NHTS

BRIEF

CHANGES IN ONLINE SHOPPING TRENDS

2017 National Household Travel Survey

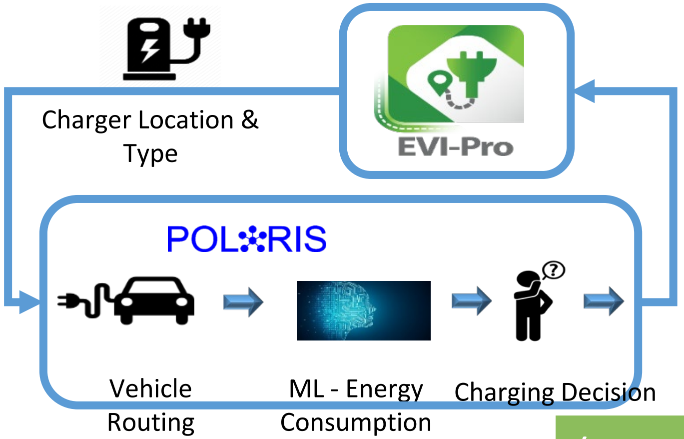
August 2018

Online shopping is a thriving market, reflecting the increasing development of information technology and convenience of electronic commerce over the last decade. In an effort to track trends associated with increased access to technology, the National Household Travel Survey (NHTS) began to query respondents ages 16 and

PROPOSED FUTURE RESEARCH

- Develop and implement agent-based freight model (supply chain, establishments as agents)
- Apply agent-based freight model to study new mobility technology impacts on VMT and energy
    - EV technologies and charging infrastructure
    - Truck platoons
    - Nighttime deliveries
    - Autonomous deliveries

    →extend other WF tools accordingly
- Integrate Freight-MEP when available



(EEMS068)

FHWA R&T Now - September/October 2017. A News Update Of Research, Technology, And Development From The U.S. Department Of Transportation (USDOT), Federal Highway Administration (FHWA). Accessed March 8, 2018 at https://www.fhwa.dot.gov/publications/rtnow/17sep_oct_rtnow.cfm

Any proposed future work is subject to change based on funding levels

SUMMARY: MAIN RESULTS

Vehicle Types	Performance Measure	Base-line	Change, % Change Relative to Baseline		
			A-High	B-High	C-High
All MDT, HDT	VMT	23.5	4.5 (19%)	15.4 (65%)	9.3 (40%)
	Fuel	4.1	-0.9 (-18%)	0.02 (0.4%)	-0.5 (-11%)
	Electricity	-	-	1.7 (.)	1.2 (.)
E-com./ Retail MDT, LDV	VMT	18.6	-15.7 (-85%)	-15 (-81%)	-2 (-11%)
	Fuel	0.6	-0.4 (-59%)	-0.4 (-68%)	-0.4 (-65%)
	Electricity	0.01	-0.01 (.)	0.8 (.)	2.8 (.)

Units (all in Millions): VMT: Miles; Fuel: Gallons; Electricity: kW-Hr

Main results:

- Truck traffic increases → mobility impacts (especially in daytime)
- Increased electrification → decreased truck fuel use
- Efficient delivery systems → net decrease in fuel use via shop trip reductions

QUESTIONS?

TECHNICAL BACK-UP SLIDES

PUBLICATIONS AND PRESENTATIONS

ANL Sponsored Research

- **Stinson, M.**, J. Auld and A. (Kouros) Mohammadian. Light Duty Vehicle Choice Models Examining Alternative Fuel Technology Preferences among Commercial Fleet Owners. Accepted for presentation at the Eleventh International Conference on City Logistics, Dubrovnik, Croatia, June 12-14, 2019.

- **Stinson, M.**, J. Auld and A. (Kouros) Mohammadian. An Agent-based Model of Freight Transportation with Emerging Trends in POLARIS. Presented at the 3rd VREF Conference on Urban Freight, Gothenburg, Sweden, October 17-19, 2018.

- **Stinson, M.**, B. Pandey, A. Enam, A. Rousseau, J. Auld. Spatiotemporal Analysis of the Freight Analysis Framework Data. Innovations in Freight Data Workshop April 9-10, 2019, Irvine, CA. Organized by the Transportation Research Board.

- **Stinson, M.**, Rousseau, A., J. Auld and A. (Kouros) Mohammadian. Vehicle Choice Models: Alternative Fuel Technology Preferences among Commercial Fleet Owners. Presented at the Volvo Research Foundation (VREF) VASI-SUFS Learning Institute, Troy, New York, August 10, 2018.

Other Recent Research

- **Stinson, M.,** Z. Pourabdollahi, V. Livshits, K. Jeon, S. Nippani, H. Zhu. A Joint Model of Mode and Shipment Size Choice Using The First Generation of CFS Public Use Microdata. Presented at the Transportation Research Board Annual Meeting, Washington D.C., Jan. 13-17, 2019.

- **Stinson, M.,** D. Briones, A. Manjarrez, B. Zou, A. Mohammadian. Vehicle Ownership Models for a Sharing Economy with Autonomous Vehicle Considerations. Presented at the Transportation Research Board Annual Meeting, Washington D.C., Jan. 13-17, 2019.

- **Stinson, M.,** J. Lin, A. Mohammadian. Linking Business Strategy to Transportation Energy Consumption and Emissions Estimates: Effects of Automobile Assembly Location Strategies. Presented at the Transportation Research Board Annual Meeting, Washington D.C., Jan. 13-17, 2019.

- Cheah, L., F. Zhao, **M. Stinson**, F. Lu, J. Ding-Mastera, V. Marzano, M. Ben-Akiva (2018). Next-Generation Commodity Flow Survey: A Pilot in Singapore: Modeling and Planning Initiatives. In E. Taniguchi and R. Thompson (Eds.) *City Logistics 2: Modeling and Planning Initiatives*. Wiley-ISTE, London. doi: 10.1002/9781119425526.ch7

CRITICAL ASSUMPTIONS AND ISSUES

- For this initial e-commerce analysis, the following assumptions were used:
  - Future parcel delivery tours use the same depots as the base year
  - Scale effects not accounted for in future
  - Generated tours are based on data from one carrier
  - E-commerce deliveries are efficient (no express deliveries in initial model)
  - E-commerce deliveries replace everyday shopping only; major shopping (e.g., appliances, cars) is still done in person

  Commentary

    - These assumptions are considered reasonable for initial estimates of Workflow shopping/delivery trade-off impacts
    - Assumptions and methodology will be refined in Q3 & Q4
- "Top-down" trip table assumption: future-year truck trip patterns (based on CMAP inputs) will be the same as in the base year

  Commentary: The CMAP trip tables have been developed over time by CMAP and are routinely calibrated to produce reasonable truck trip volumes. They are considered a sound starting point for analysis in regional freight studies.

SUMMARY: ALL RESULTS

Vehicles	Metric	Baseline	A-Low	A-High	B-Low	B-High	C-Low	C-High
All MDT, HDT Trips	**VMT (Millions)**	23.5	28.1	28.0	38.5	38.8	33.9	32.7
	Fuel (10^6 Gallons)	4.8	4.4	3.9	5.8	4.8	5.3	4.2
	Elec. (10^6 kW-Hr)	0.0	0.0	0.0	1.0	1.7	0.7	1.2
	Avg. Trip Length (Miles): MDT, HDT	6.5, 34	2.9, 33.5	2.8, 32.2	2.9, 32.1	3.1, 33	4.5, 31.4	4.6, 31.8
	Commodity Growth vs. Baseline: MDT, HDT-All (HDT-Reg., HDT-Long Haul)		6%, 6% (6%, 6%)	6%, 6% (6%, 6%)	28, 38 (34, 55)	28, 38 (34, 55)	28, 38 (34, 55)	28, 38 (34, 55)
E-commerce & Retail Shopping Only	**VMT (Millions of Miles)**							
	MDT (Delivery)	0.4	2.9	2.9	3.6	3.6	1.3	1.2
	LDV (Shopping)	18.2	0.0	0.0	0.0	0.0	14.1	15.3
	Total	18.6	2.9	2.9	3.6	3.6	15.3	16.6
	Fuel Consumption (1,000 Gallons)							
	MDT (Delivery)	42.6	253.4	210.8	262.6	200.7	89.2	68.0
	LDV (Shopping)	581.1	0.0	0.0	0.0	0.0	224.5	149.9
	Total	623.7	253.4	210.8	262.6	200.7	313.7	217.9
	Electricity (10^6 kW-Hrs)							
	MDT (Delivery)	0.0	0.0	0.0	0.4	0.8	0.2	0.2
	LDV (Shopping)	0.01	0.0	0.0	0.0	0.0	1.4	2.6
	Total	0.01	0.0	0.0	0.4	0.8	1.5	2.8

EXTRAS

ASSUMPTIONS IN MODEL SCENARIOS

Scenarios and assumptions:

<table>
<tr><th>Scenario</th><th>Year</th><th>Commodity Flow Growth Rate</th><th>E-commerce HH Delivery Rate (Approx.)</th></tr>
<tr><td>Baseline</td><td>2020</td><td>-</td><td>1 delivery per week</td></tr>
<tr><td>A</td><td>2025</td><td>Moderate</td><td rowspan="2">1 delivery per day</td></tr>
<tr><td>B</td><td rowspan="2">2040</td><td rowspan="2">High</td></tr>
<tr><td>C</td><td>3-4 deliveries per week</td></tr>
</table>

→Developed MDT/HDT trip tables using these assumptions